Fermilab Contributions to CDF Physics

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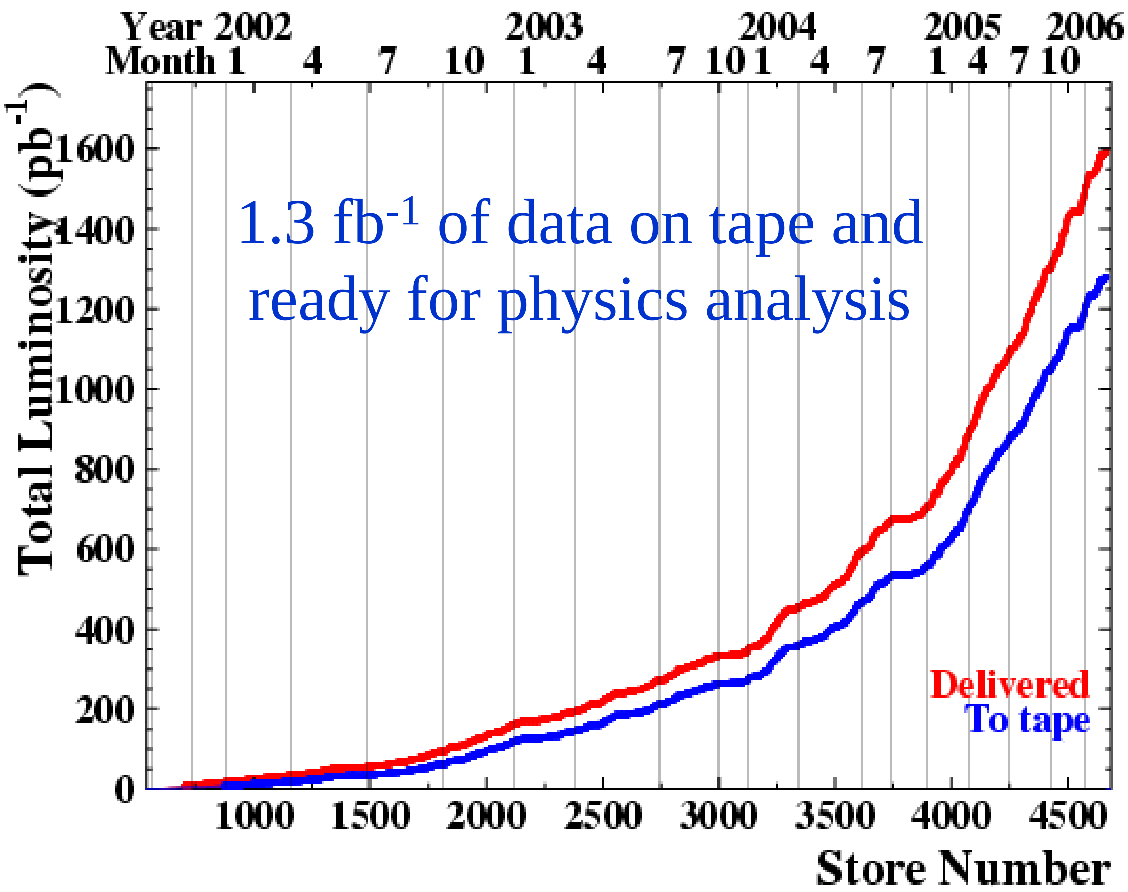
May 17^{th}, 2006
DOE Program Review

CDF Collaboration

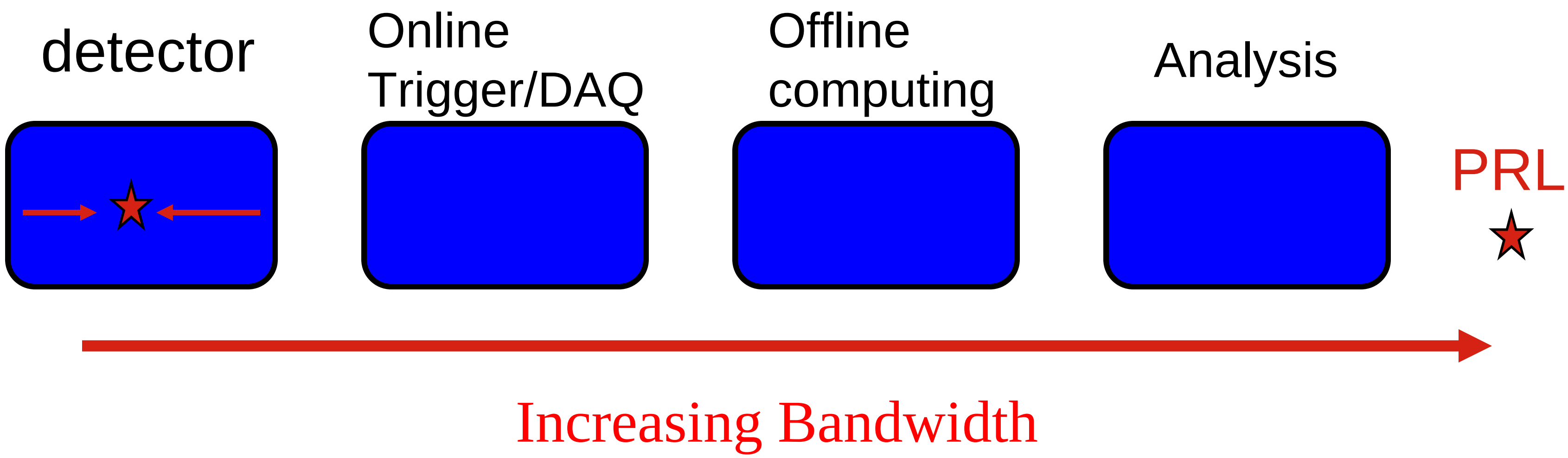
- 61 institutions from 12 countries
  - Spanning North America, Europe, and Asia
- Approximately 620 total authors
- Fermilab CDF group is the largest single group
  - 64 FNAL authors
  - Majority (42) from Particle Physics Division
  - Other members come from Computing (10), Technical (7), and Accelerator (5) divisions

Tevatron Performance



- Challenge : maintain detector performance in high luminosity environment
- Opportunity : extract compelling physics from the rapidly increasing data samples

Luminosity Challenge



- Increasing luminosity translates to need for increased bandwidth at each stage of CDF data handling
- Working to minimize the time from data collection to publication of physics results

FNAL Group Contributions

- FNAL group members have important leadership roles and responsibilities at each level of the data handling path
- Almost all group members have some technical responsibility related to maintenance and operation of the detector
- Over the past two years roughly 30 FNAL group members have held leadership positions in online and offline operations

FNAL Group Physics

- The Fermilab group also plays an important role in maximizing CDF physics output
- Roughly half of the 64 Fermilab group authors have a current, active role in CDF data analysis including ~10 full-time postdoctoral researchers
- Over the past two years 13 Fermilab group members have held leadership positions within CDF analysis groups
- High success rate at obtaining tenure-track jobs for Fermilab postdocs (seven of last eight).

Physics Overview

- CDF Run II physics priorities
  - Detailed studies of the top quark using high statistics samples
  - Searches for new physics (SUSY, Extra Dimensions, etc…)
  - Precision Standard Model measurements
- Fermilab group members making important contributions in each of these areas.
- Strong Fermilab presence in all of the CDF physics groups
  - Top, Exotics, B, Electroweak, and QCD

CDF Publications

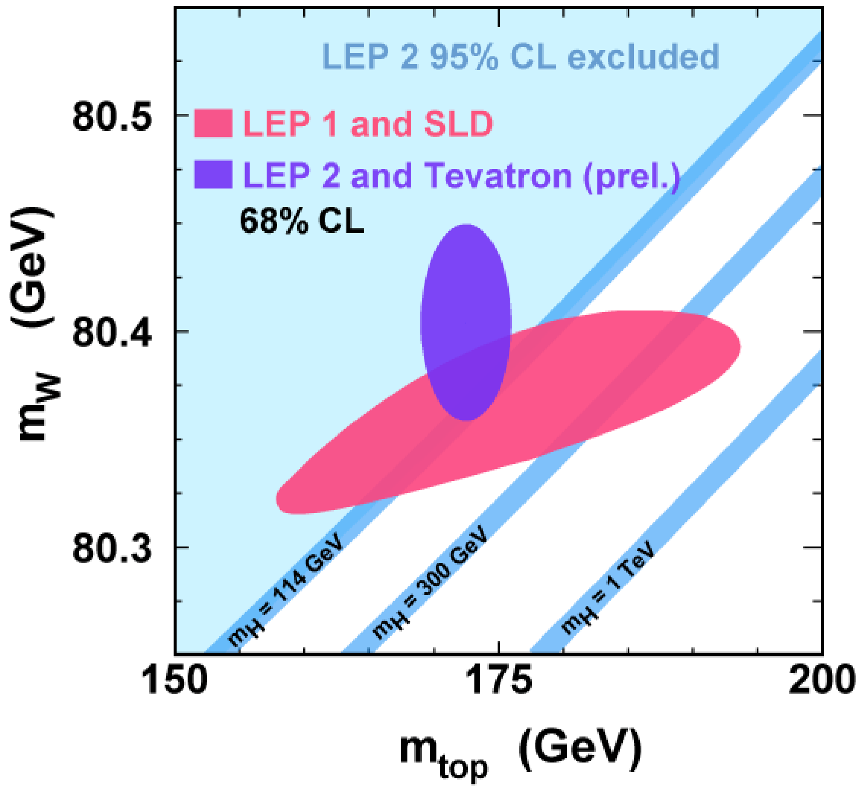
- The CDF collaboration has published 47 Run II physics papers
  - Plus 9 accepted and 18 submitted
- Fermilab group members have made a significant contribution to roughly 30% of these publications
  - PRL : 9 accepted, 5 submitted
  - PRD : 6 accepted, 2 submitted

FNAL Group Publications

- B_d, $B_s \rightarrow \mu\mu$ (PRL) Glenzinski, Lin, Thom, Yagil
- Dilepton t-tbar cross section (PRL) Glenzinski, Merkel, Thom, Wittich, Yagil
- J/Ψ and b hadron cross sections (PRD) Miao, Bishai, Tkaczyk, Lewis, Litvintsev
- Search for anomalous diphoton + MET events (PRD) Culbertson
- W/Z boson production cross sections (PRL) Hocker, James, Murat
- Diphoton production cross sections (PRL) Culbertson
- Jet shape analysis (PRD) Martinez
- W boson charge asymmetry (PRD) Nelson
- Lepton plus jets kinematic t-tbar cross section (PRD) Erbacher, Roser
- Updated B_d, $B_s \rightarrow \mu\mu$ (PRL) Glenzinski, Lin
- Template + DLM lepton plus jets top mass (PRL) Chlachidze, Velev
- Template lepton plus jets top mass (PRD) Chlachidze, Velev
- Evidence for $B_c \rightarrow J/\Psi\ \pi$ (PRL) Papadimitriou
- High mass dilepton search (PRL) Maeshima, Nelson
- Search for charged Higgs from top decays (PRL) Eusebi, Hocker
- W/Z boson production cross sections (PRD) Hocker, James, Murat
- Measurement of $\Lambda_b \rightarrow \Lambda^+_c\ \pi^-$ (PRL) Dimtri
- Inclusive jet cross section using cone algorithm (PRL) Chlebana
- Measurement of B_c lifetime (PRL) Ting
- Template dilepton top mass (PRD) Ambrose, Beretvas, Chlachidze, Velev
- Observation of $B_s \rightarrow \Psi(2S)\ \phi$ (PRL) Liu
- Search for large extra dimensions (PRL) Burkett, James, Yagil

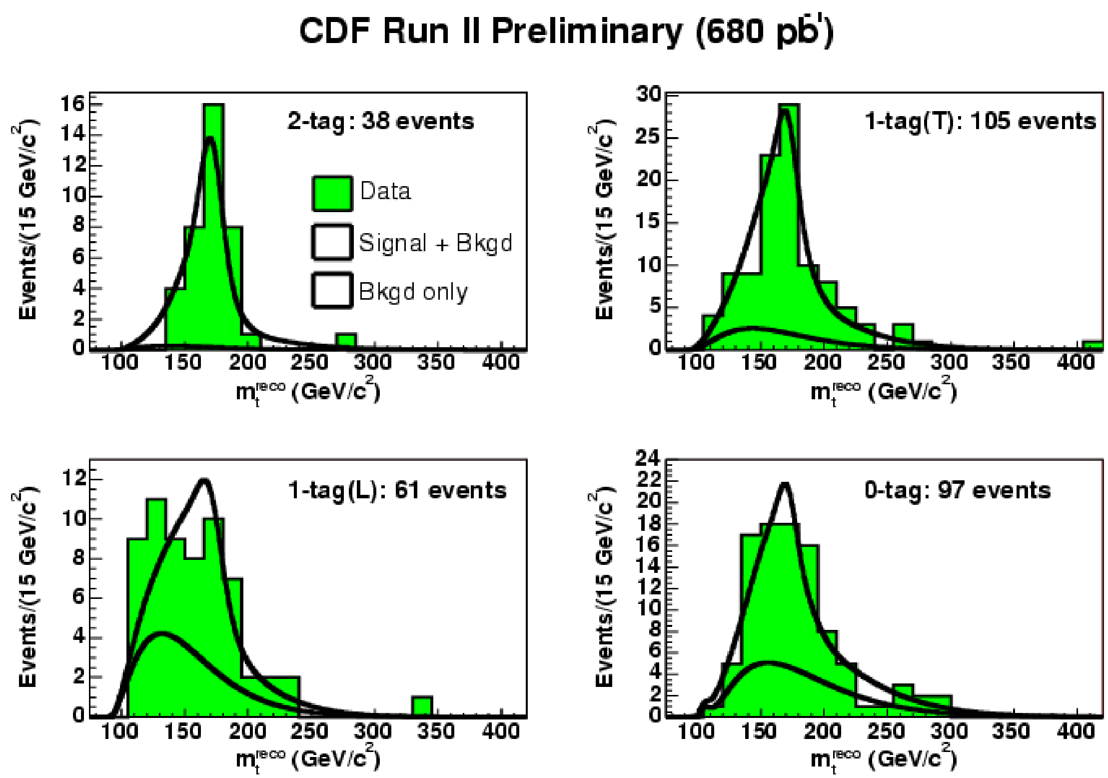
Top Quark Studies

- Top quark studies are unique to the Tevatron.
- Top quark is ~40 times heavier than the next heaviest quark suggesting a special role within the SM
- Measurement of the top quark mass constrains the SM Higgs mass



Top Mass Measurement

- CDF has measured the top mass in all available final states
- Lepton plus jets channel provides world's single highest precision top quark mass measurement



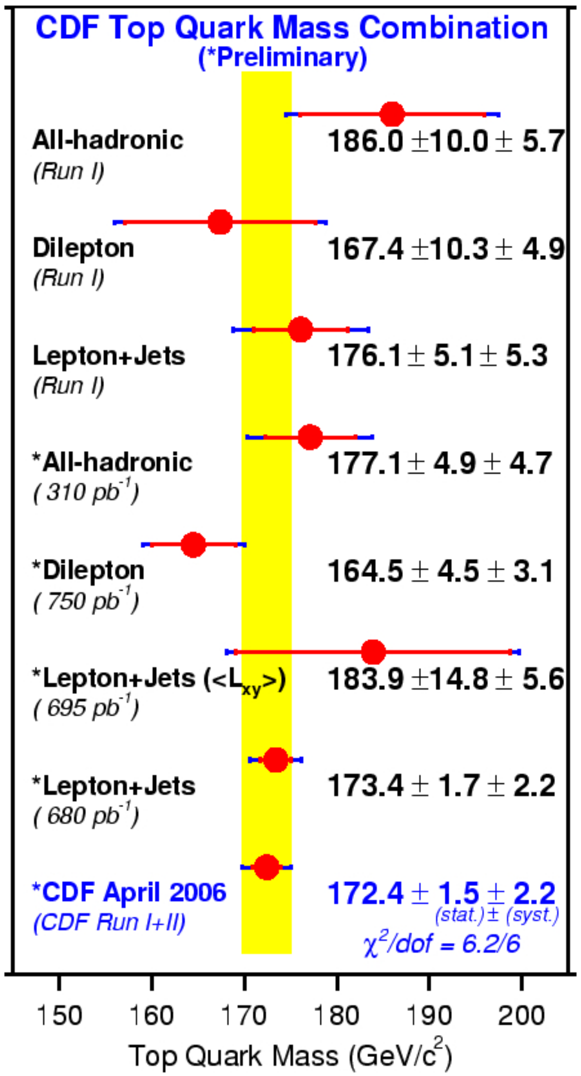
D. Ambrose, A. Beretvas
G. Chlachidze, D. Glenzinski,
G. Velev

$M_{top} = 173.4 \pm 1.7 \pm 2.2$ GeV/c^2

(Lepton plus Jets)

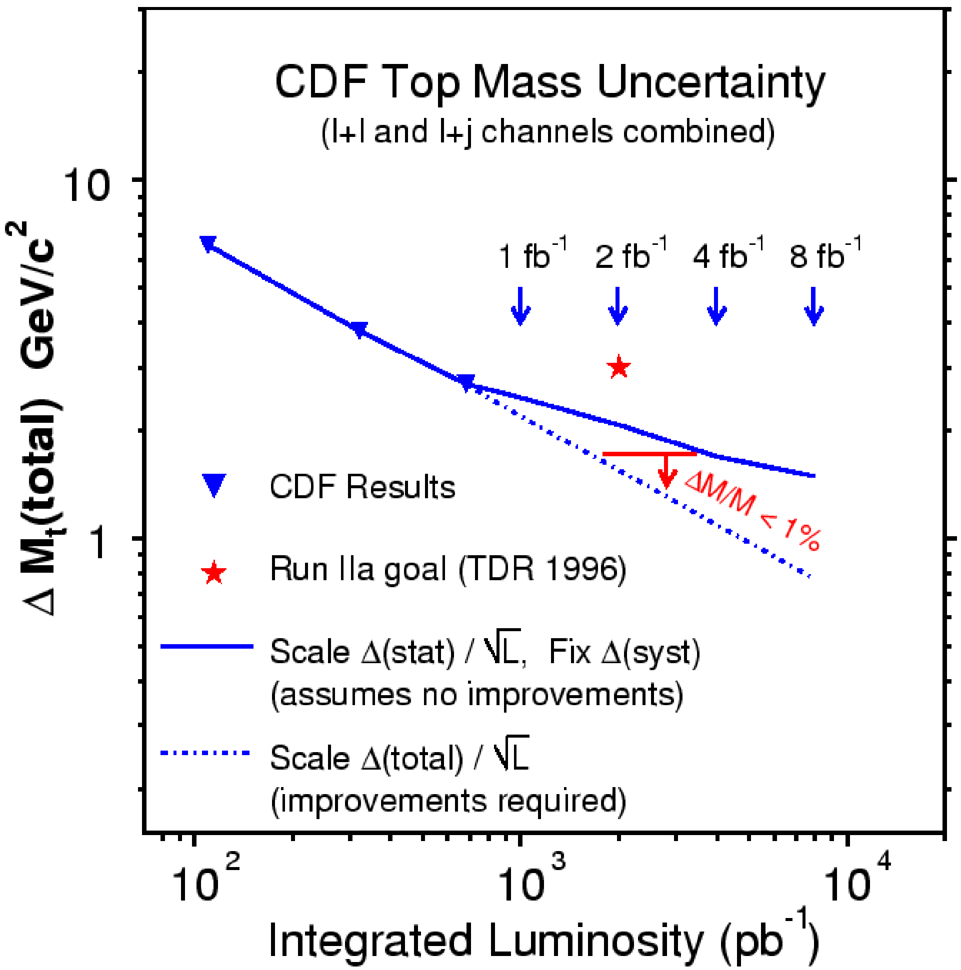
Combined Measurement

- CDF results are the world's best single measurements in each individual channel
- Combining all CDF measurements → 1.5% precision
- The combined CDF result is more precise than previous world average.



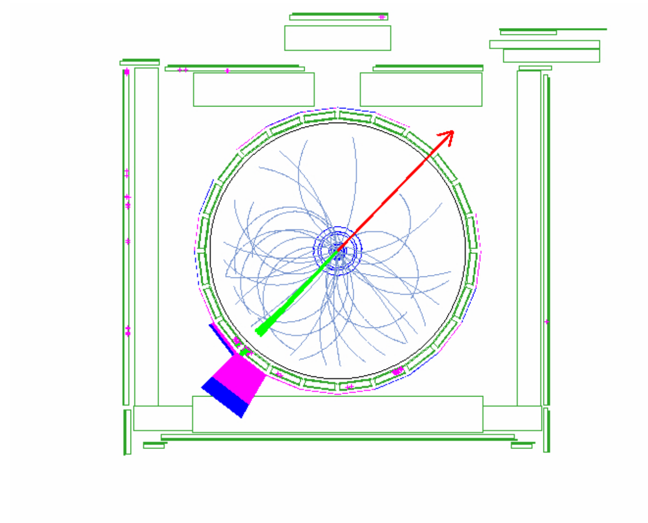
Future Prospects

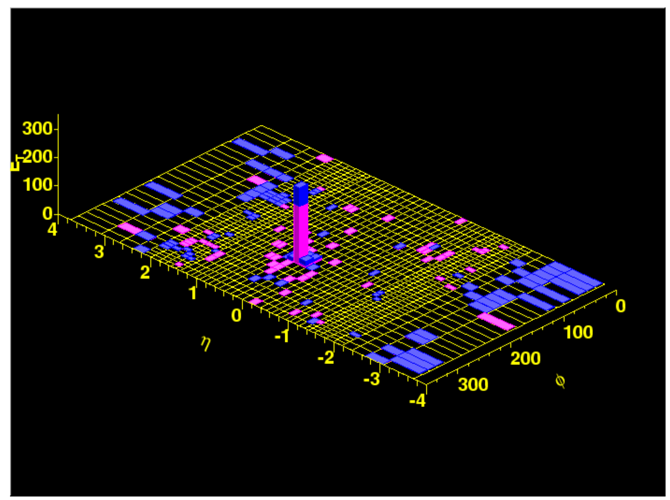
- Current result (▼) exceeds original Run II goal (★)
- Largest systematic is jet energy scale uncertainty which can be improved with more data
- CDF measurement will reach a precision of 1% using the full Run II dataset



Large Extra Dimensions

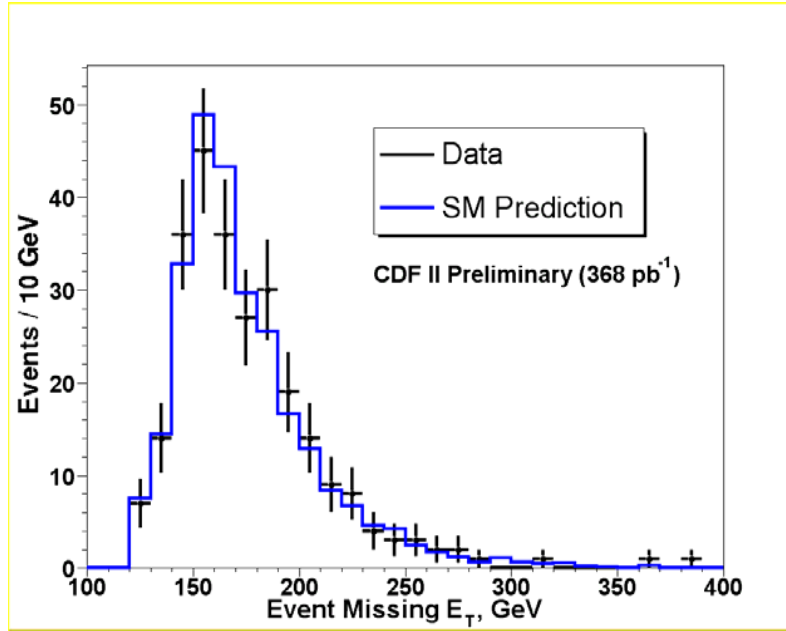
- Extra dimensions are an important component of many theories (e.g. string theories)
- Can explain the difference in the EWK and Plank scales (hierarchy problem)
- Direct graviton production at the Tevatron results in distinctive “monojet” events





Monojet Analysis

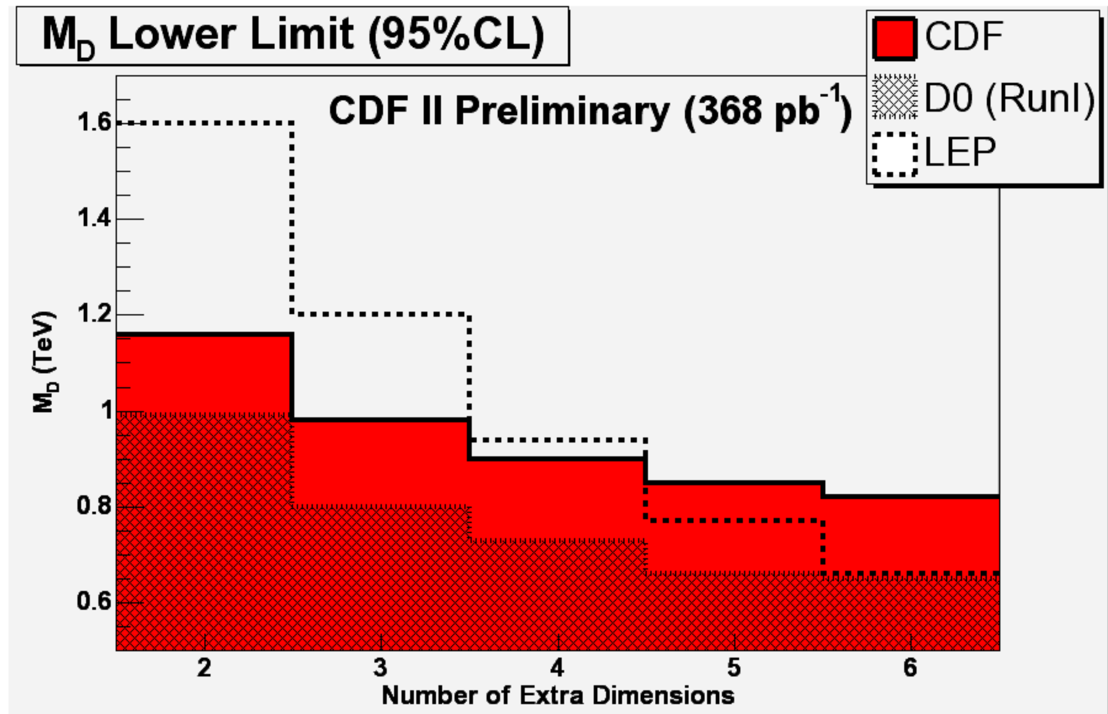
- Select events with one high E_T jet (above 150 GeV) and large missing E_T (greater than 120 GeV)
- Estimate SM backgrounds using a data-driven approach based on $W \rightarrow l\nu$ + jet and $Z \rightarrow ll$ + jet samples ($l = e,\mu$)
- Removal of non-collision background events is critical



K. Burkett, E. James, A. Yagil

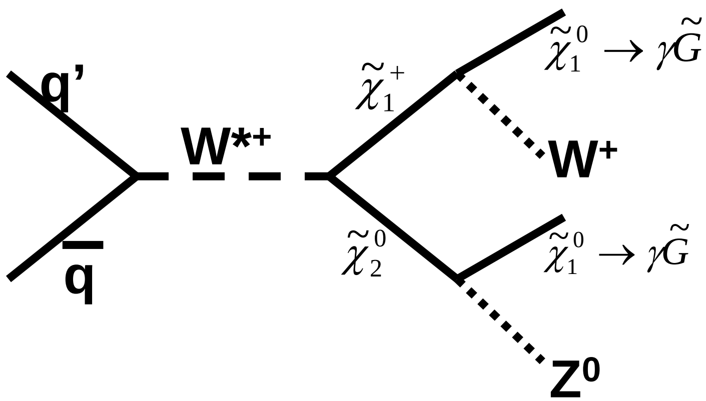
Limits on M_D

- Best lower limits on M_D for five or more extra dimensions
- New 1 fb^{-1} result (summer 2006) will have significantly improved reach



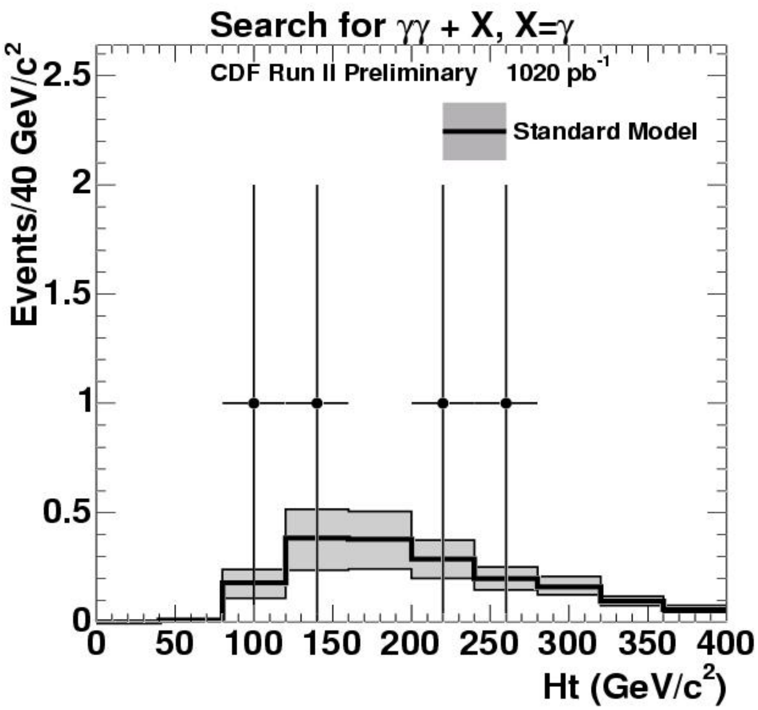
Diphoton Searches

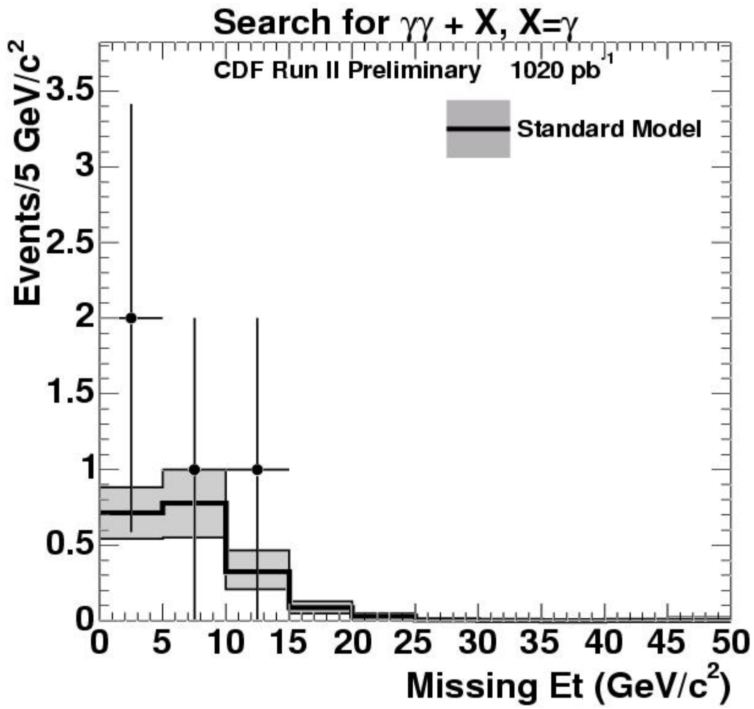
- Signature based search sensitive to a wide variety of new physics models
- Partially motivated by unusual Run I ee$\gamma\gamma$ plus missing E_T event
- Select events with two photons (E_T > 13 GeV) and some other third object X where X = photon, muon, electron, missing E_T, etc…



Gauge-mediated SUSY-breaking models

Three Photon Events

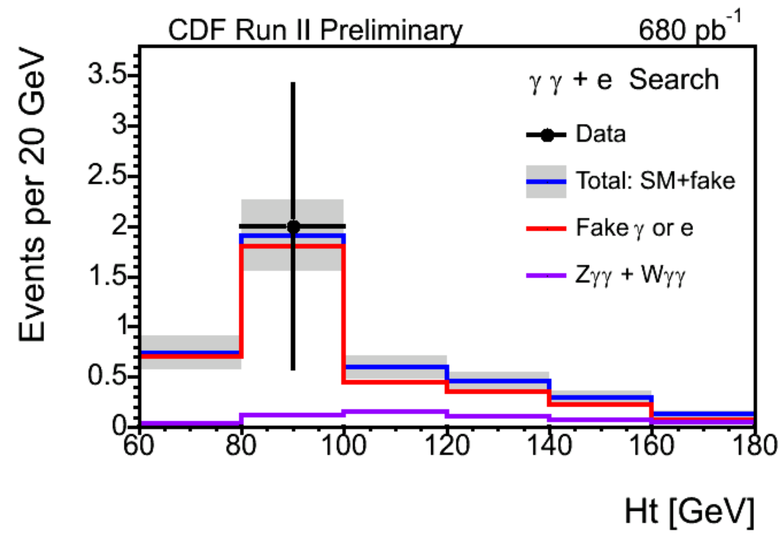


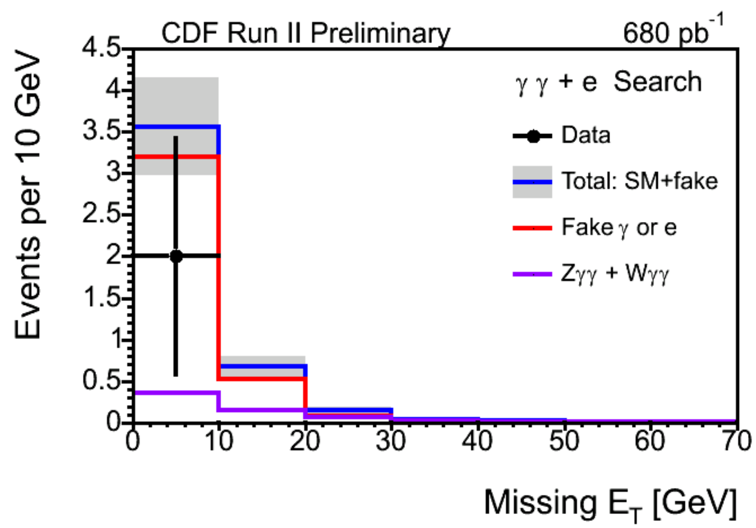


R. Culbertson, S. Pronko, E. Yu

Diphoton plus Electron Events

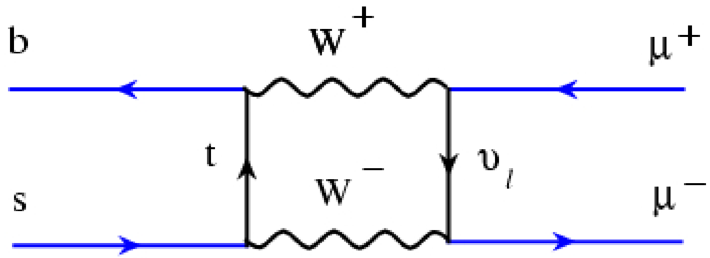
- Numbers of observed events consistent with SM background estimates
- New physics would likely appear at high H_T and/or Missing E_T

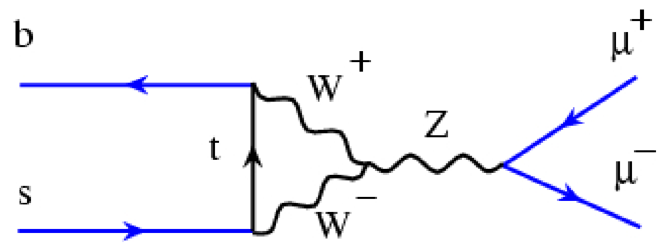




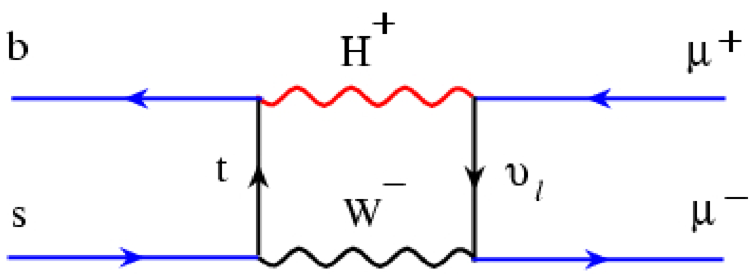
$B \to \mu\mu$ Search

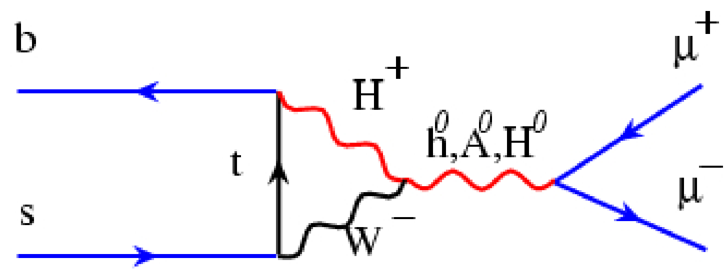
- In the SM, $BR(B_s \to \mu\mu) = 3.5 \times 10^{-9}$





- Enhanced by 1-3 orders of magnitude in SUSY

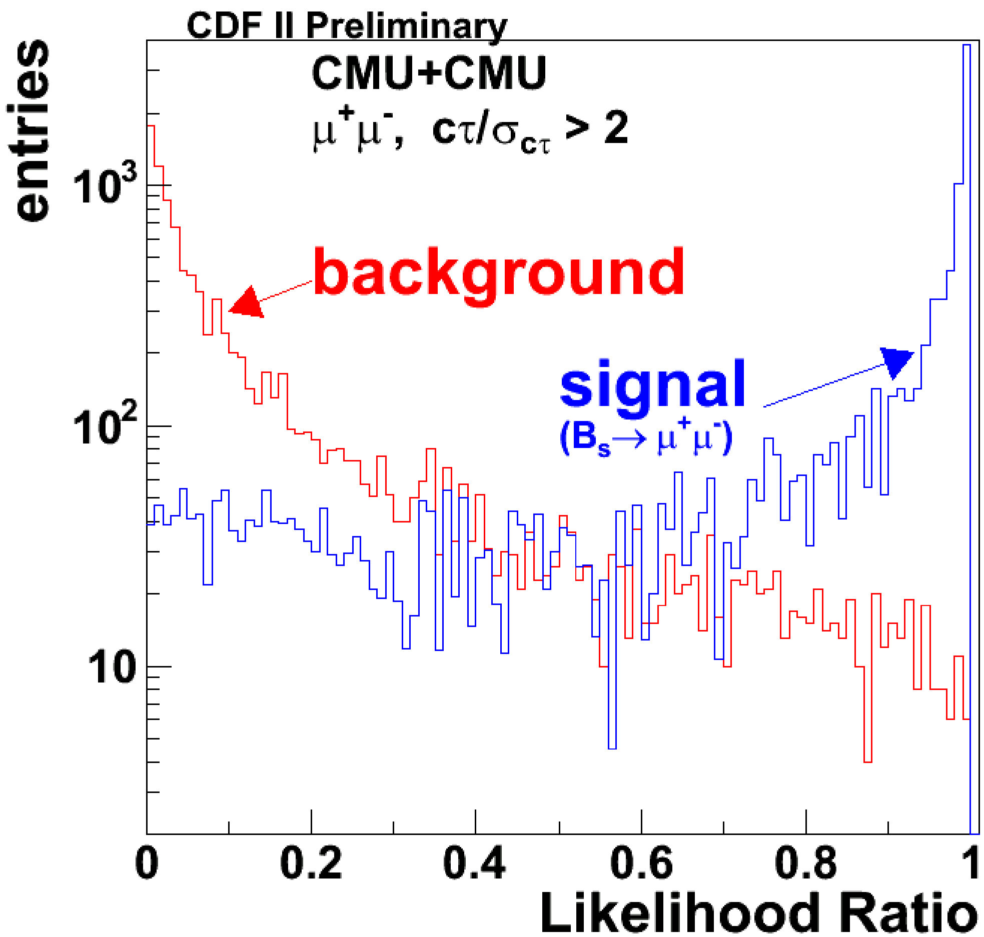




- Signal observation provides unambiguous evidence for new physics

Signal/Background Separation

- Uses a multivariate likelihood ratio based on the measured B lifetime, track isolation, and the observed consistency of the measured B hadron direction with the primary and secondary vertices



D. Glenzinski, C. Lin

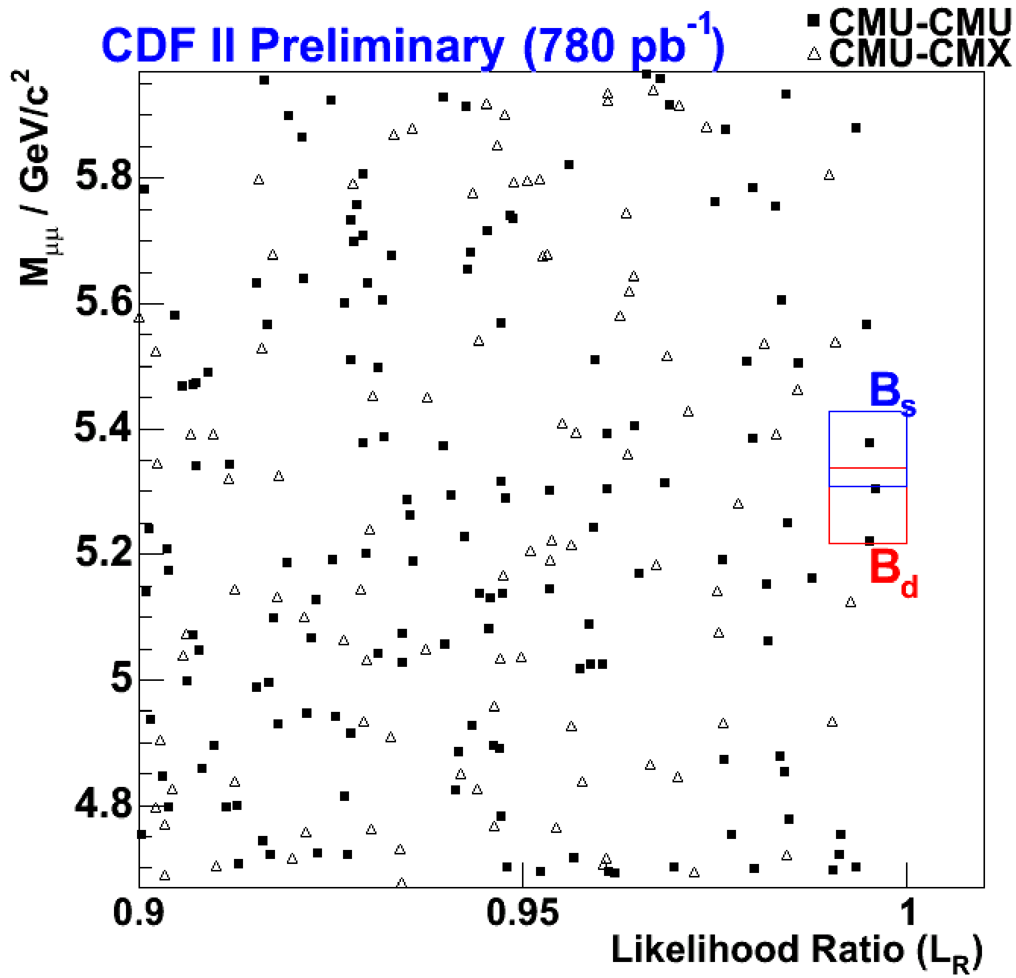
Search Window

- Separate B_s and B_d mass windows (60 MeV) provide window into the underlying flavor physics
- Observed signals consistent with background

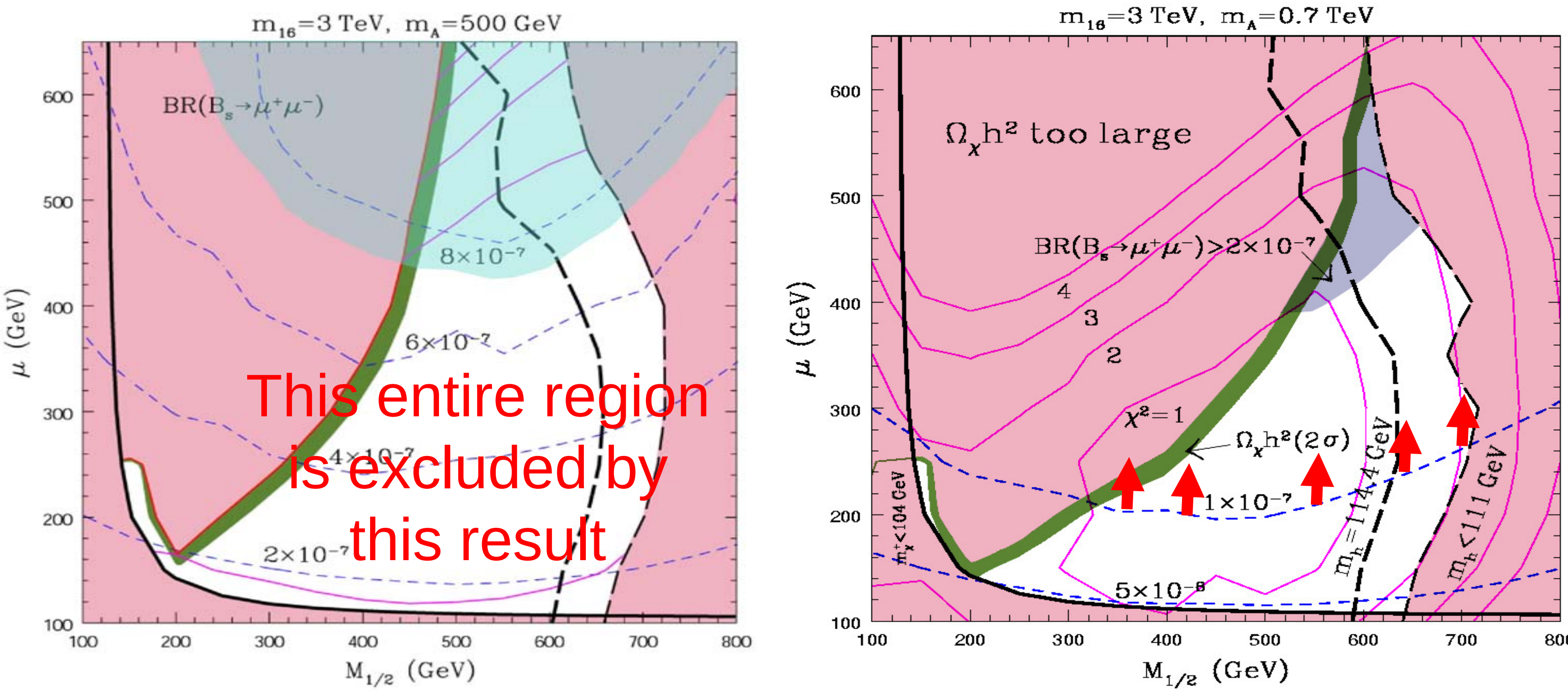
World's Best Limits :

BR($B_d \rightarrow \mu\mu$) < 1.0 x 10-7

BR($B_s \rightarrow \mu\mu$) < 3.0 x 10-8



SUSY Constraints



- SO(10) Grand unification Model (R. Dermisek et al.) from 2003 (left) and 2005 (right)

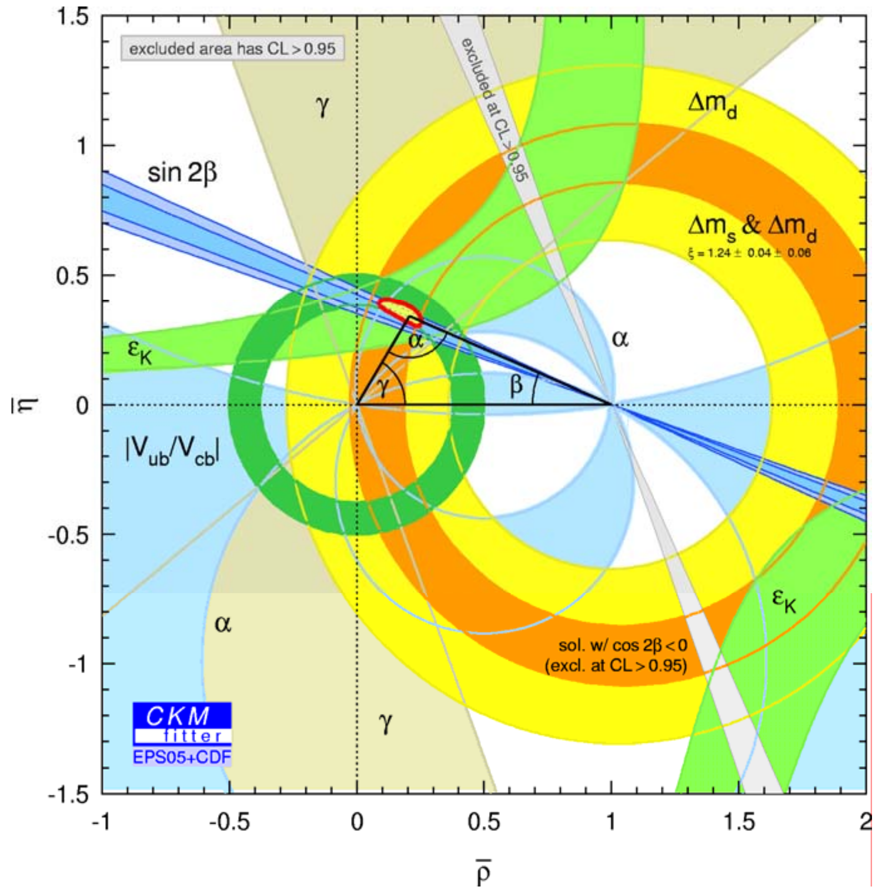
B_s Mixing

$\Delta m_s = 17.33\ ^{+0.42}_{-0.21} \pm 0.07\ ps^{-1}$

$|V_{td}| / |V_{ts}| \propto \Delta m_d / \Delta m_s$

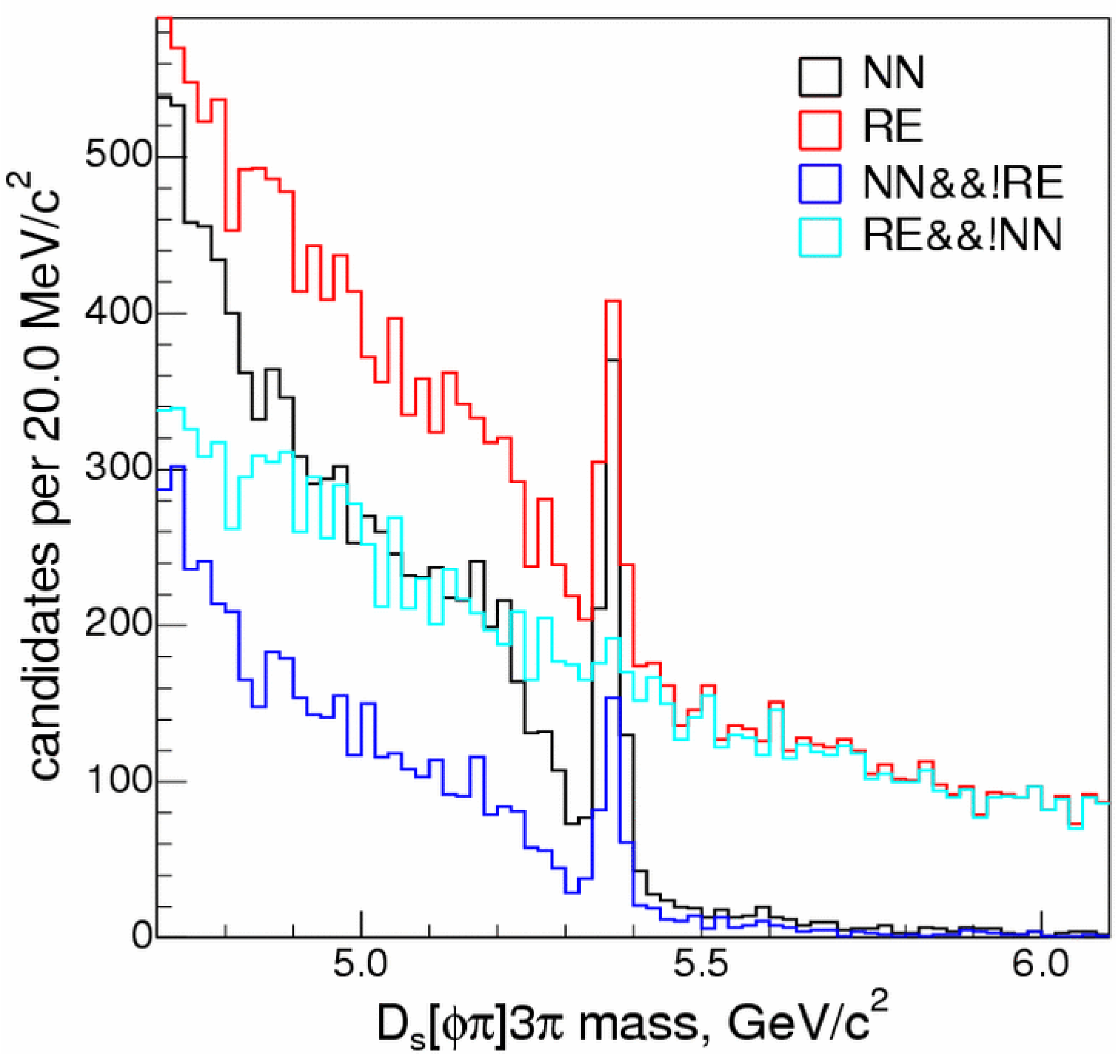
$= 0.208\ ^{+0.001}_{-0.003}\ (exp)\ ^{+0.008}_{-0.006}\ (theo)$

- New constraint is 4.5x better than previous result
- At large values of Δm_s the measurement significance is dominated by hadronic decays



Next Steps

- B_s significance is proportional to $S/\sqrt{(S+B)}$
- Neural network can be used to independently optimize event selection in each hadronic channel
- Improves measurement using current dataset



Improved Sensitivity

Table of S and B ($S/\sqrt{S+B}|_{total} = \Sigma S_i/\sqrt{\Sigma S_i + \Sigma B_i}$)

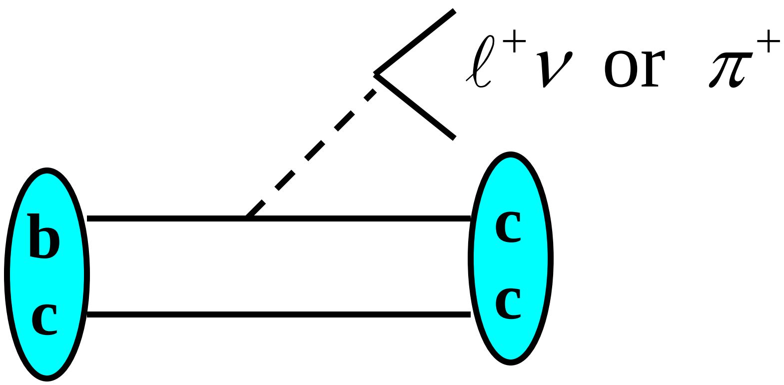
Mode	RECT cuts		NN selection	
	S	B	S	B
$B_s \to D_s^- \pi^+$, $D_s \to \phi\pi$	1430	317	1704	239
$B_s \to D_s^- \pi^+$, $D_s \to K^{*0}K$	649	328	828	293
$B_s \to D_s^- \pi^+$, $D_s \to 3\pi$	487	595	696	546
$B_s \to D_s^- (3\pi)^+$, $D_s \to \phi\pi$	421	620	649	185
$B_s \to D_s^- (3\pi)^+$, $D_s \to K^{*0}K$	185	334	425	192
$B_s \to D_s^- (3\pi)^+$, $D_s \to 3\pi$	–	–	225	162
Total $S/\sqrt{S+B}$, $5.31 - 5.42\,\mathrm{GeV}/c^2$	43.30		57.78	

- Incorporating neural network in event selection increases S/√(S+B) by 33% which is equivalent to including 77% additional data

K. Anikeev

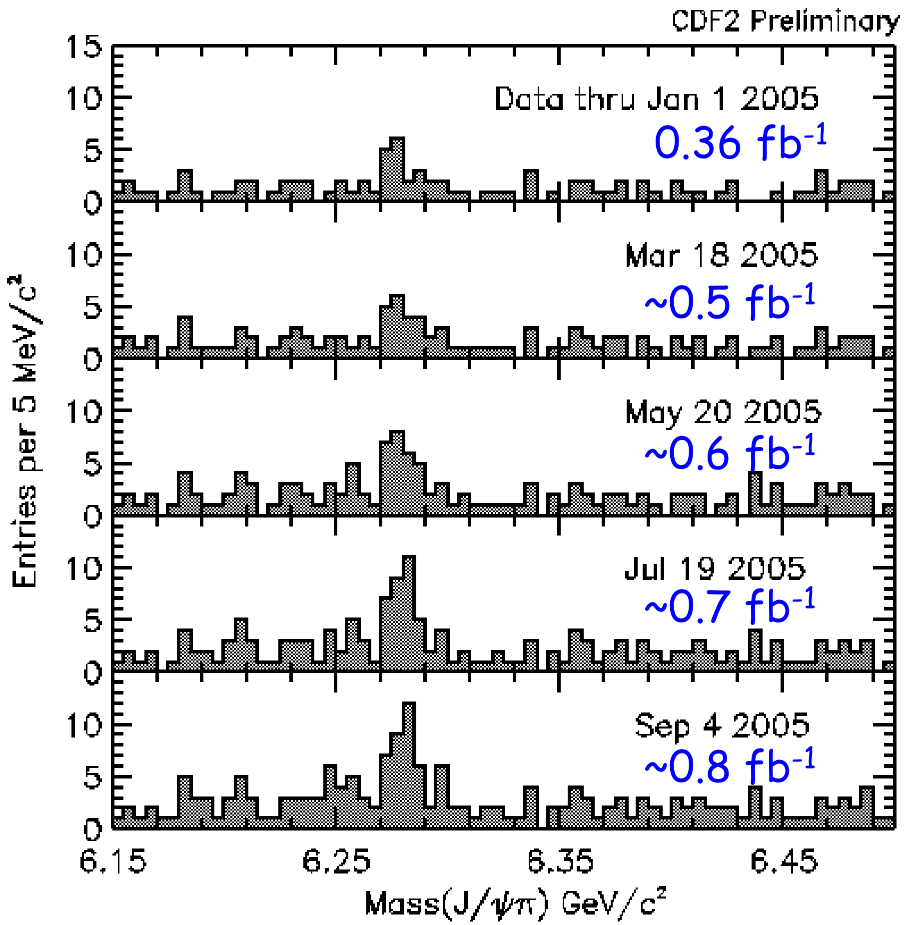
B_c Mass

- First observation of B_c ($\rightarrow J/\Psi\ l^+\nu$) made by CDF in 1998
- Precision measurement of the B_c mass provides an important test of heavy quark effective theory
- With Run II detector and greater luminosity, B_c ($\rightarrow J/\Psi\ \pi^+$) can be utilized



Mass Measurement

- In 800 pb-1, observe 39 events over a background estimate of 26 events (6σ significance)
- Measure $M(B_c) = 6275.2 \pm 4.9\ \mathrm{MeV}/c^2$
- 80x more precise than current world average



P. Lukens, S. Tkacyzk, W. Wester

Work in Progress

- Improved top mass measurement (Datta)
- W helicity in top decays (Golossanov, Hocker)
- Top spin correlations (Eusebi)
- Double charm correlation (Reisert)
- $\sigma(\chi_{c2}) / \sigma(\chi_{c1})$ in $J/\Psi\ \gamma$ (Lukens)
- B_c lifetime (Miao)
- SUSY search for high p_T dimuons (Nachtman)
- Z′ dimuon mass peak search (Nachtman)
- Search for long-lived massive particles (Snider)

Conclusions

- CDF is prepared for multi-fb^{-1} datasets
  – Have increased bandwidth from collisions to publication
- Fermilab group makes important contributions at every stage
  – Online data collection
  – Offline data processing
  – Analysis and publication